mu2e1441
21 March 2011

Comments on Extinction Measurements

Abstract: I discuss the ideas for extinction presented in other memos and reconcile some differences.

Mu2e doc-db 1375 discusses *A Proposed Combined Method For the Measurement of the Micropulse Intensity and an Extinction Measurement at 10^{-10}* based on the channel idea from doc-db 1426. The pre-conceptual scheme described in this method is similar to that proposed for MECO and subsequently for mu2e, which is described in doc-db 530-v1 (April 2009). Both have a passive channel to select a limited momentum bite. They differ in that the device in doc-db 1426 has a separate permanent magnet in the passive channel while the MECO design forgoes such a magnet and uses the bend in the PS fringe field to reduce rates and preselect an appropriate momentum particle coming from the target.

MECO proposed TOF counters surrounding a bending magnet to serve as a magnetic spectrometer to identify protons and reduce backgrounds by time of flight and dE/dx. The MECO device also has a calorimetric detector to provide energy measurement redundancy and deal with the large dynamic range. Simulations of rates in the detectors and a concern for backgrounds at a rate of one event in a few minutes motivated a choice of a relatively low momentum (around 2 GeV/c). This yields good TOF resolution, dE/dx separation of pions and protons, sufficient rates, good geometry (significant bending in the PS fringe field and the secondary magnet), a shorter and smaller aperture channel, and smaller detector footprint. The momentum distribution with a gap at 1-2 GeV/c that is shown in doc-db 1426 was not seen in the MECO studies and could be problematic if true. It should be understood in any case.

Doc-db 1375 and 1426 also discuss the possibility of TOF and calorimetric detectors in addition to the magnetic spectrometer channel. The preferred momentum is high (around 8 GeV/c) for the stated reason of reduced rate of non-signal particles at that momentum and a known production cross-section. This memo states that the TOF π-p separation is about 7σ; this appears to be high by a factor of $\sqrt{2}$ since the pion-proton difference is divided by the σ of the TOF resolution rather than by $\sigma\sqrt{2}$ as is appropriate for the difference in the expected transit time. The aperture of the channel is also miss-stated in doc-db 1375 as being 5-10 mm rather than 5-10 cm as stated in doc-db 1426

The issue of whether or not we require a magnet in the passive selection channel is open. MECO found through simulation that the rate in the calorimetric detector was predominantly from particles at the momentum of interest. Doc-db implies that an entrance channel with a magnetic bend other than that from the PS fringe field is needed, although no calculation is shown and the choice of the inlet channel angle is not informed by the rate into the channel.

Doc-db 1375 also discusses a number of ways that the absolute proton beam intensity can be measured with different devices. The signal/noise ratio accounting for most sources of backgrounds does not depend on the intensity, contrary to the statement in mu2e1375 that the backgrounds are proportional to I^2. Indeed, the fact that signal/background does not depend on rate is a major advantage of our experiment vs. $\mu \to e\gamma$. Only things like background hits contributing to the spectrometer resolution would give a signal/noise ratio that depended on rate, and MECO calculations showed that this was not a dominant contribution to the background. One would certainly want to know the relative intensity to verify that any background is not associated with micro-pulses that have abnormally high rates. Hence, measurement of the **pulse-to-pulse intensity variation** is most important. That is naturally measured in a number of ways with already planned detectors. For example:

1. The detector rates will be known pulse to pulse to very high precision by virtue of the hit rates in the spectrometer. A fully streaming DAQ does this automatically, with about 1000 hits per micro- pulse in the tracker. A triggered DAQ would require a separate measurement, for example of the number of hits in the tracker system for each micro-pulse. These could be counted in PLUs in the readout. For pulses in which events of interest occur, hit information on each wire will be available, and the number of non-track associated hits will be of order 1000, allowing an event to event measurement of the rate environment.
2. The extinction monitor was designed for MECO to give of order 50 protons per micro-pulse in the calorimetric detector. This would deposit about 100 GeV of energy in the calorimeter, and even a device of poor performance ($100\%/\sqrt{E/GeV}$) in relative energy resolution would give a 10% measurement of the flux in each pulse. The measurement will be available essentially in real time and could be sent to the accelerator controls system.
3. The upstream extinction monitor would provide a similarly precise measure of micro-pulse intensity, essentially in real time.

Measuring the **absolute intensity** on a pulse-to-pulse basis is also useful. This will require calibrating absolutely the detectors that measure the relative intensity. At BNL, segmented wire ionization chambers (SWICs) have been used routinely to measure beam profiles; when correctly calibrated they also provide absolute rate measurements. Secondary emission monitors (SEMs) also provide absolute flux measurements and can be absolutely calibrated. Both would integrate the flux over some time (e.g. one e-buncher spill), and both can be operated in a beam such as ours. The absolute calibration of a device that measures relative intensity in each micro-pulse is then derived by summing the signals in the pulse-by-pulse device over some period (1 second for example) and normalizing to the absolute flux measured in the SWIC, SEM, or other integrating device for that pulse. This would need to be done only occasionally. If desired, SWICs or SEMs could be mounted on plunging devices to allow them to be extracted. Ref. 5 from doc-db 1375 also discusses SEMs. These devices are mostly used for beam tuning and will be required for that purpose independent of our desire to have an absolute measurement of beam on target.

Alternatively, the amount of circulating beam in the storage rings will be well known, and since losses must be limited to something like 10% for reasons of radiation and activation, the integral flux coming down the beam-line (summed over some period like one de-buncher store) will be known. This will allow a calibration of any of these spill-to-spill detectors to a precision of a few percent.

Doc-db 1375 also asserts that using a diffractive signal is preferred to using a lower energy signal for two reasons. First, it has a known cross-section that could be used to validate the Monte Carlo. It is not clear to me what the purpose of a Monte Carlo is in this context, in particular in predicting the absolute flux going into the extinction monitor. The second reason given is the *fewer sources of particles near the diffracted peak.* This hasn't been shown to be true for mu2e. In particular, there are likely to be more particles that satisfy the TOF requirement if we are trying to distinguish protons from pions at 8 GeV/c, where both are very close to being fully relativistic. For example, CR muons could be a problem at the level of one in an hour, even CR muons going nearly horizontally or even slightly upward.

I also note that the upstream extinction monitor has not been described in detail. It is assumed that a rather simple telescope looking at a thin window is all that is required. I am not convinced that this will work, at least until something is known about the rate environment. The MECO proposal was to use a device similar to the downstream telescope imaging a thin window in a beam-line magnet by using the magnet fringe field to do the momentum selection. This is certainly a conservative approach for mu2e. This would clearly be easier using low momentum pions, produced at larger angles and requiring a shorter TOF system and calorimeter, better matched to the tunnel dimensions.

I would conclude that the optimal extinction monitor technology is not clear now, and that using lower momentum (~2 GeV) protons is likely the better choice. A simulation of the rate environment in locations that might house the detectors would better inform the design. In particular, locations in the experimental hall, where a smaller detector system working with low energy particles might be mounted, should be considered.